



RESEARCH MEMORANDUM

SUMMARY OF LOCATIONS AND EXTENTS OF TURBULENT AREAS

ENCOUNTERED DURING FLIGHT INVESTIGATIONS OF THE

JET STREAM FROM OCTOBER 1953 TO MAY 1954

AND NOVEMBER 1954 TO JULY 1955

By Mary W. Fetner

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SUMMARY

The locations and extents of turbulent areas encountered during flights of a Boeing B-47B airplane engaged in an investigation of the jet stream and the Sierra Mountain Wave are presented. The data were obtained from NACA VGH time-history records in cooperation with the Air Force Cambridge Research Center.

INTRODUCTION

A considerable number of studies of the structure and geographical location of the jet stream have been made in the past few years because of the importance of the jet stream to airplane operations and to weather conditions. In one of the most recent of these studies, a flight investigation utilizing Boeing B-47B airplanes was undertaken by the Air Force Cambridge Research Center (ref. 1). The National Advisory Committee for Aeronautics cooperated in this flight investigation to the extent of providing instruments for measuring the turbulence and the evaluation of the data. This report summarizes the extents of the turbulent areas and the altitudes and times at which they were encountered.

¹The information presented herein was previously made available to the U. S. military air services.

SCOPE OF DATA AND APPARATUS

The flight records covered the periods from October 31, 1953, to May 10, 1954, and November 1, 1954, to July 5, 1955. The records from 31 flights were obtained mostly over the southeastern portion of the United States during traverses along and across the axis of the jet stream. Flight altitudes for the separate traverses varied from about 25,000 feet to 40,000 feet in an attempt to obtain detailed data on parameters such as the wind and turbulence field at a given altitude in the jet stream and also to define the cross section of the jet stream. Five additional flights, March 29, 1955, to April 16, 1955, were made in the western portion of the United States to obtain data at tropopause levels in the lee side of the Sierra Mountain Range. A more detailed description of the tests is given in reference 1.

The NACA VGH recorder used to obtain the turbulence measurements for the 1953-to-1954 phase of the investigation is described in reference 2. Basically, the instrument contains two pressure capsules and an accelerometer element to record time histories of airspeed, altitude, and vertical acceleration. The recorder contained 200 feet of film, and, with the film speed of 0.31 foot per minute used in the present tests, film was available for approximately $10\frac{1}{2}$ hours of flight. In general, continuous records were taken from the time of take-off to the time of landing. One-minute timing marks as well as an additional series of reference marks for synchronizing the time measurements with other meteorological observations recorded in the airplane were impressed on the VGH records.

For the 1954-to-1955 phase of the investigation, the accelerometer element was removed from the VGH recorder and a highly sensitive airspeed cell was installed to measure the fluctuations in indicated airspeed in turbulent air. These fluctuations provided a measure of the longitudinal gust components of the turbulence.

EVALUATION AND PRESENTATION OF DATA

In evaluating the VGH records obtained from the 1953-to-1954 phase of the investigation, the portions of the records where continuous disturbances of the airspeed and acceleration traces occurred were assumed to represent turbulent areas. In all turbulent areas encountered during this phase of the tests, however, the acceleration increments and airspeed fluctuations were too small to be read with sufficient accuracy to assign numerical values to the intensity of the turbulence. On this basis, it appears that the turbulence in these areas was of light intensity.

For the 1954-to-1955 phase of the investigation, the turbulent areas were defined by the portions of the records which contained horizontal gust components as measured from the mean flight speed of at least 5 feet per second (true). This does not infer that, in all portions of a given area of turbulence, gust velocities of at least 5 feet per second were continuously encountered. Large portions of the areas designated as turbulent contained gust velocities of lower magnitude which probably were not discernible to the flight personnel. No correction for the response of the airspeed system of the VGH recorder was made in reading the fluctuations from the records since the detailed lengths and sizes of the tubing used in installing the instrument are not known. Because of the low gust intensities and lack of information on the response of the airspeed system, it was considered impractical to assign numerical values to the turbulence intensities for the 1954-to-1955 phase of the investigation. As a result, only the locations and extents of the turbulent areas could be determined from the records.

The locations of the turbulent areas are listed for each flight in table I in terms of the elapsed time and reference marks from take-off. Also given in table I are the extent of each area of turbulence as determined by the time during which the airplane was in the turbulent region and the flight pressure altitude at the time turbulence was encountered. The time and reference number when cruising altitude was reached and when descent was started are noted in the table for each flight and are referenced from take-off in order to provide a basis for correlating the locations of the turbulence areas with other meteorological measurements taken in the airplane.

REMARKS

The turbulence encountered during the flights summarized in table I was generally of light intensities. As has been indicated, the gust accelerations experienced during the 1953-to-1954 phase of the investigation were below the reading threshold of the VGH records. It is estimated that the maximum acceleration increments for most areas of turbulence encountered for the 1953-to-1954 phase was about 0.1g. Acceleration increments of 0.1g for the B-47 airplane at 30,000 feet would correspond to true gust velocities of about 7 fps to 10 fps. For the 1954-to-1955 phase of the tests, the maximum true gust velocities as evaluated from the airspeed records were 20 fps and 24 fps for the turbulent areas starting at 26.6 and 77.6 minutes, respectively, for the flight of November 24, 1954, and

17 fps for the turbulent area starting at 149.6 minutes on April 10, 1955. Correlation of the turbulence data in table I with other characteristics of the jet stream is beyond the scope of this report.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 20, 1955.

REFERENCES

1. Endlich, R. M., Harney, Patrick, McLean, G. S., Rados, Robert M., Tibbets, O. J., and Widger, W. K., Jr.: Project Jet Stream - The Observation and Analysis of the Detailed Structure of the Atmosphere Near the Tropopause. Bull. Am. Meteorol. Soc., vol. 35, no. 4, Apr. 1954, pp. 143-153.
2. Richardson, Norman R.: NACA VGH Recorder. NACA TN 2265, 1951.

TABLE I.- SUMMARY OF JET-STREAM TURBULENCE DATA ON THE BOEING B-47

Location of turbulence referenced from take-off				Pressure altitude, ft	Extent of turbulence, miles	Remarks	
Start		End				Time cruise began, min	Time descent began, min
Time, min	Reference mark	Time, min	Reference mark				
Flight 3; October 31, 1953							
89.5	---	90.4	---	34,000	7.7	15.8	189.3
130.6	---	133.5	---	33,900	24.6		
153.0	---	166.9	---	38,400	116.6		
173.5	---	190.0	---	38,400	132.8		
Flight 4; October 31, 1953							
40.6	20	44.3	22	30,000	32.2	15.9, reference mark 8	200.6, reference mark 100
54.7	27	83.1	41	30,200	203.6		
85.9	43	97.1	48	30,200	76.3		
Flight 5; December 8, 1953							
19.7	10	21.2	11	30,000	13.1	15.3, reference mark 8	237.4, reference mark 115
68.5	33	69.3	34	30,000	6.8		
74.0	36	74.7	36	30,000	5.9		
81.5	39	82.4	40	30,000	7.7		
90.3	44	91.9	44	30,000	13.5		
96.9	47	101.9	49	30,000	31.3		
118.8	57	119.5	58	30,000	6.0		
Flight 6; December 15, 1953							
17.2	89	22.3	115	30,000	27.1	17.2, reference mark 90	(a)
40.3	209	48.6	252	30,000	70.1		
53.9	280	59.2	308	30,000	40.5		
72.7	379	79.3	414	30,000	40.5		
108.0	565	111.6	584	34,000	29.6		
124.2	651	124.7	653	34,000	4.3		
Flight 7; January 6, 1954							
37.1	---	38.2	---	30,000	9.3	17.1	(a)
46.3	---	47.2	---	30,000	7.6		
57.1	---	58.6	---	30,000	12.6		
80.0	---	80.5	---	30,100	4.3		
117.2	---	118.5	---	34,000	10.9		
159.8	---	168.1	---	34,000	50.9		
171.1	---	177.4	---	34,000	47.7		
183.0	---	186.3	---	34,000	18.5		
192.6	---	204.7	---	36,000	87.6		
208.0	---	209.4	---	36,000	11.7		
216.3	---	223.5	---	36,000	61.6		
Flight 8; January 13, 1954							
44.5	244	45.4	249	30,000	7.7	14.6, reference mark 80	238.6, reference mark 1,326
88.6	490	92.2	509	30,000	17.4		
98.2	543	102.7	568	30,000	38.6		
107.1	593	111.3	616	30,000	36.1		
121.0	670	125.9	698	30,000	36.0		
145.6	809	147.0	816	34,000	11.9		
162.4	903	164.2	913	34,000	15.3		
171.4	953	172.2	958	34,000	6.8		
175.8	973	178.5	988	34,000	23.0		
182.3	1,009	210.5	1,168	34,000	190.9		
219.1	1,217	224.8	1,248	34,000	40.9		
228.2	1,268	229.1	1,273	34,000	7.7		
234.8	1,305	238.6	1,326	34,000	32.4		

^aComplete record not obtained.

TABLE I.- SUMMARY OF JET-STREAM TURBULENCE DATA ON THE BOEING B-47 - Continued

Location of turbulence referenced from take-off				Pressure altitude, ft	Extent of turbulence, miles	Remarks	
Start		End				Time cruise began, min	Time descent began, min
Time, min	Reference mark	Time, min	Reference mark				
Flight 9; February 25, 1954							
19.8	105	21.4	113	30,000	12.6	16.3, reference mark 86 (b)	(a)
56.3	300	57.2	305	30,000	7.0		
62.5	334	71.9	384	30,000	63.7		
74.1	396	76.0	407	30,000	14.8		
108.8	584	110.7	594	32,000	15.3		
114.0	612	118.6	637	32,000	37.1		
142.7	769	144.8	780	34,000	17.6		
157.8	851	160.2	865	34,000	20.1		
162.6	877	165.3	892	34,000	17.5		
200.5	1,125	203.2	1,139	36,000	23.6		
Flight 10; March 4, 1954							
23.9	126	24.7	131	36,000	6.6	19.8, reference mark 105	281.3, reference mark 1,526
99.1	533	99.8	537	36,000	5.8		
107.1	576	109.1	587	36,000	16.5		
121.4	654	121.9	657	36,000	4.3		
164.5	889	165.2	892	36,000	6.0		
188.0	1,017	189.4	1,024	36,000	11.6		
192.4	1,041	195.2	1,056	36,000	13.5		
213.8	1,158	214.9	1,164	36,000	9.4		
Flight 11; March 8, 1954							
39.4	209	40.5	215	30,000	9.6	14.6, reference mark 77	271.2 reference mark 1,467
41.9	222	45.8	243	30,000	34.0		
Flight 13; March 15, 1954							
40.1	207	49.2	255	32,000	78.9	15.8, reference mark 83	184.3, reference mark 985
53.6	279	58.6	305	32,000	43.8		
75.0	393	75.6	397	32,000	5.3		
127.1	672	127.9	677	32,000	7.2		
145.2	770	145.7	773	32,000	4.4		
148.1	785	148.7	789	32,000	5.1		
157.7	837	159.4	846	32,000	14.9		
163.2	867	167.5	890	32,000	29.8		
176.2	941	176.9	945	32,000	6.1		
Flight 14; March 17, 1954							
20.1	105	20.8	110	34,000	6.0	16.7, reference mark 88	312.0 reference mark 1,681
54.8	289	55.5	293	34,000	5.9		
60.6	319	68.6	362	34,000	67.0		
150.5	799	151.3	803	36,000	7.1		
Flight 15; April 2, 1954							
54.1	289	55.4	296	34,000	11.1	18.1, reference mark 96	261.3, reference mark 1,415
78.0	418	78.6	421	34,000	5.1		
94.3	506	98.4	528	34,000	34.9		
118.7	638	123.3	663	34,000	32.4		
146.6	790	148.2	799	34,000	14.1		
170.5	920	171.2	924	34,000	6.2		
173.7	937	176.0	950	34,000	20.3		
201.5	1,089	202.0	1,091	34,000	4.4		
213.1	1,152	213.9	1,156	34,000	6.7		

^aComplete record not obtained.^bTime referenced from end of climb.

TABLE I.- SUMMARY OF JET-STREAM TURBULENCE DATA ON THE BOEING B-47 - Continued

Location of turbulence referenced from take-off				Pressure altitude, ft	Extent of turbulence, miles	Remarks	
Start		End				Time cruise began, min	Time descent began, min
Time, min	Reference mark	Time, min	Reference mark				
Flight 16; April 8, 1954							
33.8	181	40.3	216	36,000	56.7	20.7, reference mark 111	196.0, reference mark 1,056
66.9	360	70.7	379	36,000	53.2		
127.6	687	142.6	768	36,000	109.6		
149.3	804	150.9	813	36,000	14.0		
160.1	862	164.4	886	36,000	37.0		
173.8	936	180.9	974	36,000	60.9		
Flight 17; April 12, 1954							
32.6	192	33.3	196	36,000	5.8	21.8, reference mark 128	239.6, reference mark 1,425
42.3	249	46.5	273	36,000	28.3		
78.0	468	87.2	512	36,000	74.1		
181.7	1,078	187.2	1,110	36,000	43.7		
Flight 18; April 14, 1954							
54.4	54	56.0	56	36,000	14.0	20.6, reference mark 20	(a)
60.4	60	61.9	62	36,000	13.1		
Flight 19; May 4, 1954							
81.3	82	82.5	83	34,000	10.2	19.7, reference mark 21	306.8, reference mark 307
136.7	137	138.4	139	34,000	7.8		
268.5	269	269.2	270	34,000	6.1		
Flight 20; May 6, 1954							
96.2	97	98.2	99	33,500	17.5	22.2, reference mark 23	(a)
116.7	118	131.3	132	33,500	114.4		
134.3	135	135.7	137	33,500	12.2		
143.4	144	148.8	150	36,000	46.3		
188.2	189	189.3	190	36,000	9.3		
242.7	244	247.5	248	36,000	29.1		
258.3	259	268.2	269	36,000	61.8		
273.3	274	274.3	275	36,000	8.6		
281.0	282	284.5	285	36,000	30.0		
288.4	289	294.8	296	36,000	45.5		
Flight 21; May 10, 1954							
36.9	38	38.0	39	34,800	9.7	20.9, reference mark 22	266.5, reference mark 267
74.2	75	74.7	75	34,800	4.4		
127.1	128	130.1	131	15,000	11.1		
198.8	199	210.7	211	25,000	58.8		
226.4	227	229.3	230	25,000	22.4		
244.5	245	259.7	260	34,800	131.5		
262.7	263	263.4	264	34,800	6.0		
Flight 24; November 1, 1954							
90.5	---	95.2	---	35,500	40.1	20.5	286
109.9	---	115.0	---	35,500	43.1		
175.5	---	188.7	---	35,500	112.2		
271.2	---	277.6	---	35,000	53.3		

^a Complete record not obtained.

TABLE I.- SUMMARY OF JET-STREAM TURBULENCE DATA

ON THE BOEING B-47 - Continued

Location of turbulence referenced from take-off (a)		Pressure altitude, ft	Extent of turbulence, miles	Remarks	
Time of start, min	Time of end, min			Time cruise began, min	Time descent began, min
Flight 27; November 10, 1954					
18.6	24.4	34,000	42.6	24	272
41.6	45.1	35,500	29.6		
129.5	133.3	35,500	33.4		
175.3	178.3	35,500	25.8		
195.9	214.3	35,500	155.8		
254.8	265.3	35,500	90.7		
267.2	273.6	35,500	56.1		
Flight 29; November 24, 1954					
26.6	48.0	35,500	160.9	21	303.5
77.6	93.3	35,500	104.6		
97.3	158.1	35,500	182.2		
205.4	209.8	35,500	38.7		
273.3	276.4	35,500	28.5		
282.4	297.1	35,500	107.8		
Flight 36; February 16, 1955					
41.9	46.0	36,000	35.0	20	208
86.0	87.5	36,000	12.8		
95.6	96.8	36,000	10.2		
105.1	107.5	36,000	20.4		
114.1	116.1	36,000	17.1		
148.5	155.0	36,000	12.8		
159.0	160.7	36,000	14.7		
198.0	199.5	36,000	12.9		
Flight 37; February 18, 1955					
35.3	40.4	34,000	44.2	24	366
41.3	43.1	34,000	15.3		
70.6	92.3	34,000	188.0		
137.8	138.7	34,000	7.8		
159.3	161.5	34,000	18.8		
166.1	168.2	36,000	17.9		
176.2	177.5	36,000	11.2		
224.8	238.5	38,000	118.8		
255.2	265.7	38,000	93.4		
309.3	315.0	38,000	50.2		
339.0	343.6	37,000	39.5		
347.0	351.2	37,000	35.4		

^aNo reference mark.

TABLE I.- SUMMARY OF JET-STREAM TURBULENCE DATA

ON THE BOEING B-47 - Continued

Location of turbulence referenced from take-off (a)		Pressure altitude, ft	Extent of turbulence, miles	Remarks	
Time of start, min	Time of end, min			Time cruise began, min	Time descent began, min
Flight 38; February 21, 1955					
36.3 82.7 117.9 137.5 215.0	42.3 84.8 118.8 140.5 215.5	36,000 40,000 40,000 40,000 40,000	50.5 9.0 3.5 13.2 2.2	20	255
Flight 39; March 3, 1955					
124.7 194.5 200.0 213.7	125.6 196.4 202.4 214.6	37,000 38,000 37,500 37,000	4.0 8.8 20.7 4.1	21	280
Flight 40; March 29, 1955					
-----	-----	-----	-----	All gust velocities in turbulent areas were less than 5 fps (true)	
Flight 41; April 1, 1955					
20.5 33.1 36.7 47.3 73.9 85.5 110.4 114.0	24.2 33.8 38.8 48.2 74.5 89.6 111.1 127.3	35,000 35,000 35,000 35,000 34,000 39,500 40,000 40,000	29.1 5.5 16.0 6.5 4.5 36.2 6.3 123.5	16	221
Flight 42; April 10, 1955					
31.0 127.0 149.6 176.1 189.2 192.0 212.7	36.3 127.5 167.2 179.4 191.0 193.9 219.9	30,000 30,000 30,000 25,000 25,000 25,000 25,000	48.4 4.0 139.0 25.9 14.7 15.1 58.3	16	221
Flight 43; April 13, 1955					
90.3	91.7	34,000	11.7	17	230
Flight 44; April 16, 1955					
167.5 180.7	168.0 184.4	34,000 34,000	4.0 30.2	18	224

^aNo reference mark obtained from intervalometer.

TABLE I.- SUMMARY OF JET-STREAM TURBULENCE DATA
ON THE BOEING B-47 - Concluded

Location of turbulence referenced from take-off		Pressure altitude, ft	Extent of turbulence, miles	Remarks	
(a)				Time cruise began, min	Time descent began, min
Time of start, min	Time of end, min				
Flight 45; May 31, 1955 to June 1, 1955					
-----	-----	-----	-----	All gust velocities in turbulent areas were less than 5 fps (true)	
Flight 46; June 3, 1955					
21.9	23.9	30,000	17.66	19.0	395.1
Flight 47; June 27, 1955					
-----	-----	-----	-----	All gust velocities in turbulent areas were less than 5 fps (true)	
Flight 48; June 28, 1955					
247.7	250.2	35,000	20.96	22.8	393.3
264.4	265.0	35,000	5.12		
290.4	291.8	35,000	11.83		
293.0	308.3	35,000	128.27		
313.2	321.4	38,000	67.92		
324.3	325.3	38,000	8.35		
326.0	327.9	38,000	16.06		
328.3	330.0	38,000	14.62		
332.5	333.4	38,000	7.74		
357.1	358.7	38,000	14.03		
375.5	377.3	38,000	7.04		
388.8	390.0	38,000	10.60		
390.7	391.0	38,000	2.63		
Flight 49; June 30, 1955					
188.8	189.0	34,000	0.85	13.4	201.3
199.0	201.3	35,000	19.28		
Flight 50; July 5, 1955					
-----	-----	-----	-----	All gust velocities in turbulent areas were less than 5 fps (true)	

^aNo reference mark obtained from intervalometer.